STATE OF CALIFORNIA
DEPARTMENT OF TRANSPORTATION

INSTRUMENTATION FINAL REPORT

MEASUREMENT OF THE CURING TEMPERATURE IN MASS CONCRETE POURS

Dublin 580/680 Interchange

9 January 2001

Prepared for

Ric Maggenti

By

Engineering Service Center
Materials Engineering and Testing Services
Instrumentation Services Branch

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ORIGINAL SIGNED BY
Danny L. Callaway

Report By: ______________________________
Danny Callaway, P. E.
Instrumentation Services

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DANNY L. CALLAWAY
No. 25333
Exp. 9/30/04
MECHANICAL
STATE OF CALIFORNIA

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I. DISCUSSION

During the curing process concrete undergoes an exothermic chemical reaction. Generally this heat production is of little consequence; it is released over a rather long period and is easily dissipated to the surrounding environment.

Large concrete structures (mass concrete) however present a problem, the heat generated within the body of the structure cannot be dissipated quickly, and rather large temperature gradients can develop between the center and the surface of the structure. These temperature gradients during the cure period produce cracks in the finished concrete structure. These cracks serve as entry portals for chlorides that have a deleterious effect on the reinforcing steel.

Temperature gradients can be controlled (reduced) in a variety of manners. Replacing the mixing water with ice and pre-cooling the aggregate, to reduce the maximum temperature, are methods that are used but with limited effectiveness. Constructing large structures in small stages, or lifts, can be done, but it is slow and the finished structure is weakened at the cold joints in the concrete. Another way to reduce these temperature gradients is to modify the mix design (adding fly ash for example) to slow the curing process. Slowing the curing process means longer construction times, which may be objectionable. Installing tubing within the structure and circulating a cooling fluid through this tubing to maintain a rather constant temperature is another option. Both of these last techniques where investigated in this study.

Construction at the 580/680 interchange in Dublin included a number of mass concrete pours. Data from six of these pours is included here. These six pours used three different mix designs as follows; at bents 3, 5, 6 & 10, of the north east connector, RMC Lonestar mix number 3415 was used, at bent 4, of the north east connector, RMC Lonestar mix number 6251 was used and at bent 18, of the south east connector, RMC Lonestar mix number 29866 was used. Concrete mix designs are included in Section 3 of this report.

At the five locations on the north east connector only the mix design was changed. Data at these locations was collected at four depths along one edge of the structure and at the same depths near the center of the structure. This data presents a "global" temperature distribution in the structure.

At bent 18 of the south east connector auxiliary cooling of the structure was provided. The cooling equipment circulated chilled water through three 1-inch diameter black steel pipe mats within the structure (see Figure 2 for schematic of this equipment). In addition to the "global" temperature values at the other locations, data was collected between the pipes circulating the cooling fluid.

The data presented in the following pages represents a portion of a continuing California Department of Transportation study of concrete curing temperatures in mass concrete pours.

Figure 1. Location of work

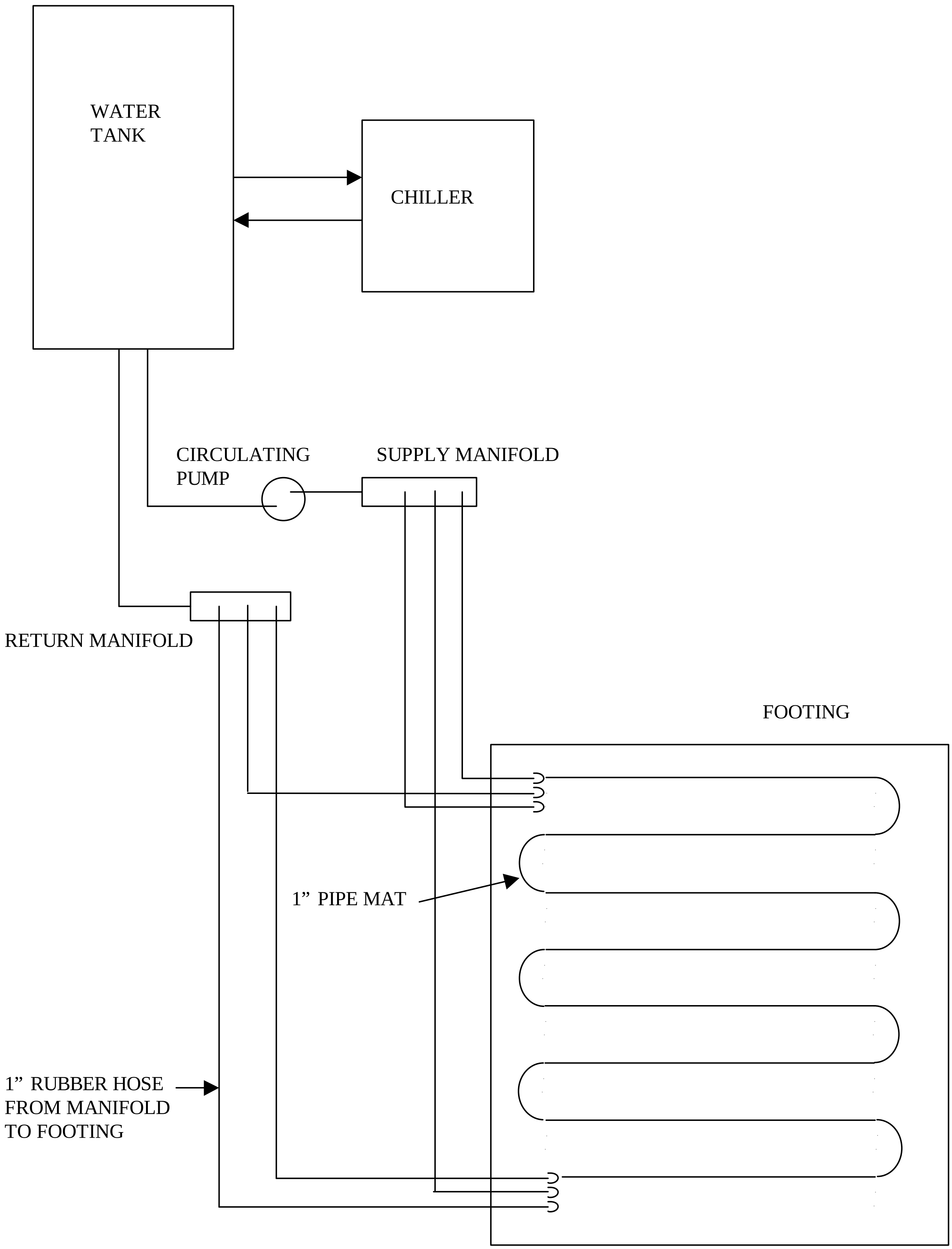


Figure 2. Schematic diagram of cooling equipment (no scale). The flow in each of the cooling pipe mats was approximately 15 gallons per minute.

II. EQUIPMENT LIST

Data Logger
Campbell Data Logger Model 21X
With 16 channel input multiplexer Model AM416

Thermocouple Wire
Type T Thermocouple wire

Computers:
Fieldworks computer -- Pentium 166 with Windows 95

Data Acquisition Software
Campbell PC-208W

Digital Camera
Kodak DC200 Camera with Picture Easy 2 software

Data Reduction & Report Preparation Software
Microsoft Excel Office 97 Version
Microsoft Word Office 97 Version

III. CONCRETE MIX DESIGNS

RMC LONESTAR
TECHNICAL SERVICES

4750 Nords Canyon Road. Suite A
San Ramon. California 94583
(925) 866-2780 FAX (925) 866-2983

Group 238	*Mix Number 3415*

Report No 52161
06/18/1999
05081817

CALTA 1.5 6.18 C+F 35% RET
FCI
ATTN: DAVE HORN

#04-233924 INTERCHANGE ALTS
580-680 PLEASANTON
DUBLIN

MATERIALS DESCRIPTION

CEMENT TYPE II MODIFIED ASTM C-150
POZZ INTERNATIONAL FLYASH ASTM C-618 CLASS F
CALMAT 1 1/2" X 3/4" ASTM C-33 SIZE 4
CALMAT 1" X #4 ASTM C-33 SIZE 57
CALMAT CONCRETE SAND ASTM C-33
POZZOLITH 300R ASTM C-494 TYPE D

This mix will produce concrete meeting the design criteria when produced, sampled and tested in accordance with ASTM C-94 and UBC. Mix will be adjusted as required by UBC Section 2604 to maintain the noted strength level.

Cementitious Material	6.18 sk
Maximum Size Aggregate	1.5 in.
Slump	3.50 ± 0.50 in.
W/C+F ratio	0.46
Entrained Air	n/a

Code	Material	Solid Volume	SSD Quantity
1011	CEMENT TYPE II MODIFIED	1.92 cf	378 lbs
9001	POZZ INTERNATIONAL FLYASH	1.41 cf	203 lbs
1126	CALMAT 1 1/2" X 3/4"	4.48 cf	750 lbs
1127	CALMAT 1" X #4	6.85 cf	1150 lbs
2112	CALMAT CONCRETE SAND	7.78 cf	1296 lbs
9046	POZZOLITH 300R	0.00 cf	17 oz
	Air (1.00 %)	0. 27 cf	
	Water (32.0 gal.)	4.29 cf	267 lbs
	Totals	27.00 cf	4044 lbs

Uses: MASS CONCRETE.
Note: REPLACES REPORT 46352 MIX 6251.
Note: MIX FOR PUMP OR TAILGATE PLEASE HAVE YOUR CONCRETE PUMPING COMPANY VERIFY THE PUMPABILIT OF THIS MIX.
Note: PLEASE FORWARD STRENGTH DATA TO RMC LONESTAR TECHNICAL SERVICES FOR STATISTICAL ANALYSIS PER ASTM C-94 SECTION 14.4

	Additions

RMC LONESTAR
TECHNICAL SERVICES

4750 Nords Canyon Road. Suite A
San Ramon. California 94583
(925) 866-2780 FAX (925) 866-2983

Group 238	***Mix Number 6251***

CALTA 1.5 6.18 C+F 25% RET

Report No 46352
06/26/1998
05061817

FCI CONSTRUCTION
ATTN: CURT

#04-233924 INTERCHANGE ALTS
580-680 PLEASANTON DUBLIN

MATERIALS DESCRIPTION

CEMENT TYPE II MODIFIED ASTM C-150
POZZ INTERNATIONAL FLYASH ASTM C-618 CLASS F
CALMAT 1 1/2" X 3/4" ASTM C-33 SIZE 4
CALMAT 1" X #4 ASTM C-33 SIZE 57
CALMAT CONCRETE SAND ASTM C-33
POZZOLITH 300R ASTM C-494 TYPE D

This mix will produce concrete meeting the design criteria when produced, sampled and tested in accordance with ASTM C-94 and UBC. Mix will be adjusted as required by UBC Section 2604 to maintain the noted strength level.

Cementitious Material	6.18 sk
Maximum Size Aggregate	1.5 in.
Slump	3.50 ± 0.50 in.
W/C+F ratio	0.46
Entrained Air	n/a

Code	Material	Solid Volume	SSD Quantity
1011	CEMENT TYPE II MODIFIED	2.21 cf	435 lbs
9001	POZZ INTERNATIONAL FLYASH	1.01 cf	145 lbs
1126	CALMAT 1 1/2" X 3/4"	4.48 cf	750 lbs
1127	CALMAT 1" X #4	6.85 cf	1150 lbs
2112	CALMAT CONCRETE SAND	7.90 cf	1316 lbs
9046	POZZOLITH 300R	0.00 cf	17 oz
	Air (1.00 %)	0. 27 cf	
	Water (32.0 gal.)	4.28 cf	267 lbs
	Totals	27.00 cf	4063 lbs

Uses: MASS CONCRETE.
Note: · MIX FOR PUMP OR TAILGATE PLEASE HAVE YOUR CONCRETE PUMPING COMPANY VERIFY THE PUMPABILIT OF THIS MIX.
Note: · PLEASE FORWARD STRENGTH DATA TO RMC LONESTAR TECHNICAL SERVICES FOR STATISTICAL ANALYSIS PER ASTM C-94 SECTION 14.4

	Additions

RMC LONESTAR
TECHNICAL SERVICES

4750 Nords Canyon Road. Suite A
San Ramon. California 94583
(925) 866-2780 FAX (925) 866-2983

Group 238	***Mix Number 29866***

MOD 8.5 C+F+MET ½” DELVO SP

Report No 58238
06/19/2000
21085058

FCI CONSTRUCTION
ATTN: DAVE HORN

#04-233924 INTERCHANGE ALTS
580-680 PLEASANTON DUBLIN, CA

MATERIALS DESCRIPTION

CEMENT TYPE II MODIFIED ASTM C-150
POZZ INTERNATIONAL FLYASH ASTM C-618 CLASS F
METAKAOLIN
CLAYTON ROCK 1/2" X #4 ASTM C-33
ELIOT CONCRETE SAND ASTM C-33
DELVO STABILIZER ASTM C 494
RHEOBUILD 1000 ASTM C-494 TYPE F

This mix will produce concrete meeting the design criteria when produced, sampled and tested in accordance with ASTM C-94 and UBC. Mix will be adjusted as required by UBC Section 1905 to maintain the noted strength level.

Cementitious Material	8.50 sk
Maximum Size Aggregate	1/2 in.
Slump	See Note in.
W/C+F+MET	0.31
Entrained Air	n/a

Code	**Material**	**Solid Volume**	**SSD Quantity**
1011	CEMENT TYPE II MODIFIED	3.05 cf	600 lbs
9001	POZZ INTERNATIONAL FLYASH	1.11 cf	160 lbs
9844	METAKAOLIN	0.26 cf	40 lbs
1203	CLATON ROCK 1/2" X #4	9.12 cf	1600 lbs
2107	ELIOT CONCRETE SAND DELVO	9.18 cf	1529 lbs
8112	STABILIZER	0.00 cf	24 oz
9053	RHEOBUILD 1000		192 oz
	Air (1.00 %)	0. 27 cf	
	Water (30.0 gal.)	4.01 cf	250 lbs
	Totals	27.00 cf	4179 lbs

Uses: MASS CONCRETE.TEST FOOTING
Note: SLUMP WILL BE FLOWABLE
Note: · MIX FOR PUMP OR TAILGATE PLEASE HAVE YOUR CONCRETE PUMPING COMPANY VERIFY THE PUMPABILIT OF THIS MIX.
Note: · HOLD WATER TO DESIGN. THEN ADD HRWR FOR A FLOWABLE MIX. HRWR DOSAGE APPROXIMATE
Note: METRIC MIX BATCHED AND ORDERED IN POUNDS/CUBIC YARDS. ONE CUBIC YARD APPROXIMATELY 0.75 CUBIC METERS.

	Additions

IV. FIELD DIARY

NORTH EAST CONNECTOR BENT 4

6 July 1999
Installed data acquisition equipment at the site

7 July 1999
Contractor poured footing

3 August 1999
Data acquisition equipment was removed from site

NORTH EAST CONNECTOR BENT 3

15 July 1999
Installed data acquisition equipment at the site

16 July 1999
Contractor poured footing

2 August 1999
Data acquisition equipment was removed from site

NORTH EAST CONNECTOR BENT 5

3 August 1999
Installed data acquisition equipment at the site

4 August 1999
Contractor poured footing

17 August 1999
Data acquisition equipment was removed from site

NORTH EAST CONNECTOR BENT 6

18 August 1999
Installed data acquisition equipment at the site

26 August 1999
Contractor poured footing

8 September 1999
Data acquisition equipment was removed from site

NORTH EAST CONNECTOR BENT 10

21 September 1999
Installed data acquisition equipment at the site

22 September 1999
Contractor poured footing

4 October 1999
Data acquisition equipment was removed from site

SOUTH EAST CONNECTOR BENT 18

15 November 2000
Installed data acquisition equipment at the site

16 November 2000
Contractor poured footing

28 November 2000
Data acquisition equipment was removed from site

V. PHOTOGRAPHS

Figure 3. Typical footing and bridge column rebar prior to mass pour.

Figure 4. Data acquisition equipment. In the top photo the Campbell Datalogger is shown configured for 8 channels of temperature data. In the bottom photo the multiplexer is used to monitor 25 channels of data.

Figure 5. Components of the cooling system, Bent 18 . Top the chiller and the generator used to power it along side of the water tank. Bottom the supply and return manifolds.

Figure 6. Typical completed footing.

VI. FOOTING/THERMOCOUPLE LAYOUT

The overall dimensions of the six footings studied are shown in Table 1 below.

The thermocouple installation was done after the contractor had completed all of his work prior to pouring the concrete. Thermocouple wire was attached to surplus rebar, with nylon cable zip ties, and lowered into position from on top of the top reinforcement mat.

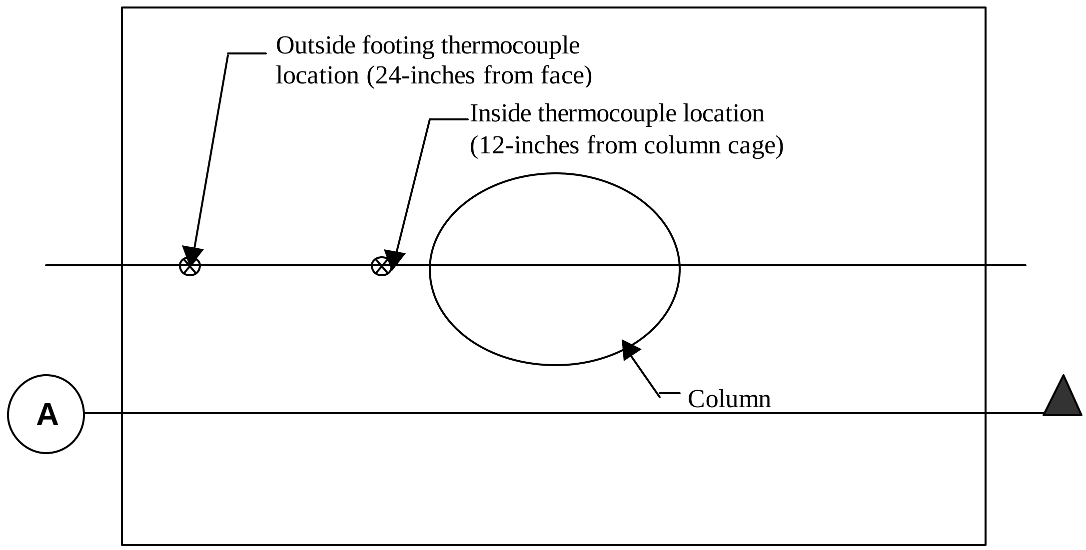
The bars used for the “global” temperature data where surplus hooks that connected the top and bottom reinforcing mats, the top and bottom thermocouples where connected to the bar approximately 9-inches from each end. The middle two thermocouples where each installed 1/3 of the distance between these, one was 1/3 up from the bottom and the other was 1/3 down from the top.

To measure the temperature gradient between the cooling pipes in bent 18 of the south east connector a shorter (4-foot) surplus bar was used. Since adjacent pipes where 3 feet apart, the outside thermocouples where attached 30-inches apart and the two interior thermocouples where positioned 10 inches inside either of these.

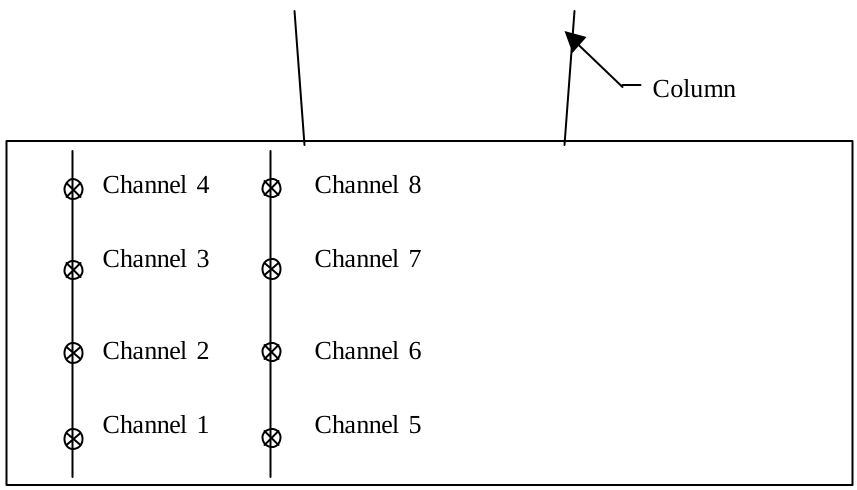
The active connection in the end of the thermocouple wire was 2 to 3 inches beyond the connection of the wire and the rebar. This was done to minimize any localized effect from the conduction of heat through the reinforcing steel; it does however mean that the final position could be several inches from the intended position.

Location	**Length**	**Width**	**Depth**
North East Connector Bent 3	35’-6”	26’-0”	10’-0”
North East Connector Bent 4	35’-6”	26’-0”	10’-0”
North East Connector Bent 5	39’-0”	32’-0”	10’-0”
North East Connector Bent 6	35’-6”	36’-0”	11’-6”
North East Connector Bent 10	39’-0”	32’-0”	10’-0”
South East Connector Bent 18	38’-0”	38’-0”	11’-6”

Table 1. Footing dimensions



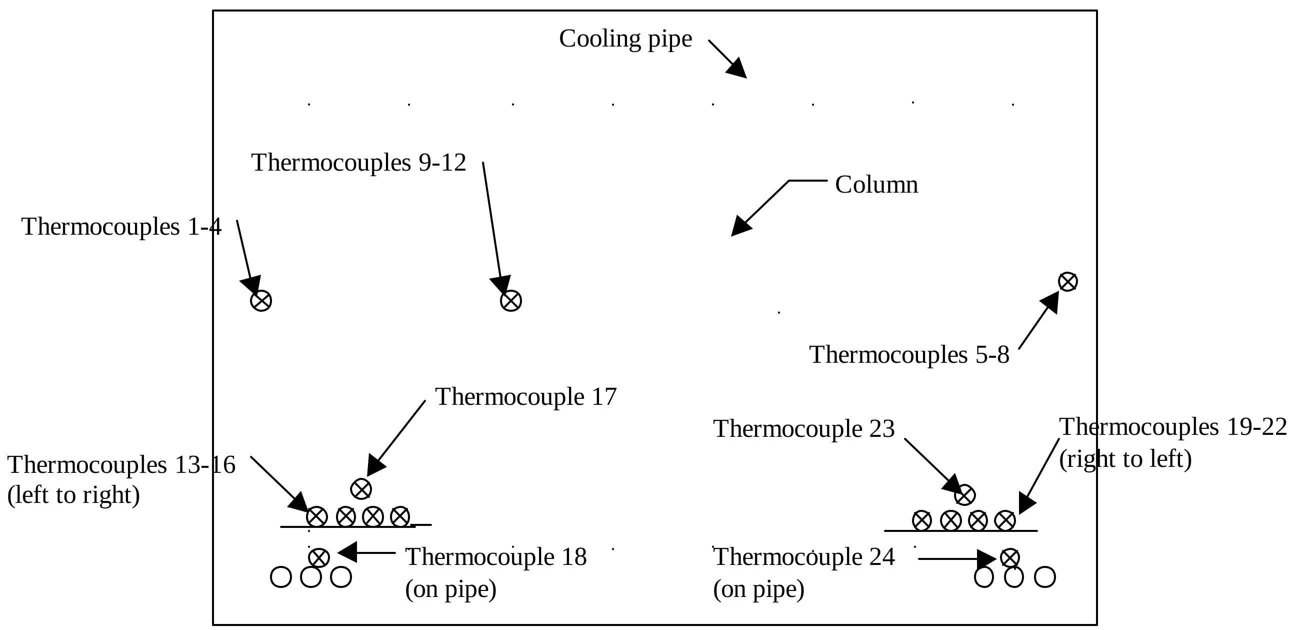
FOOTING PLAN



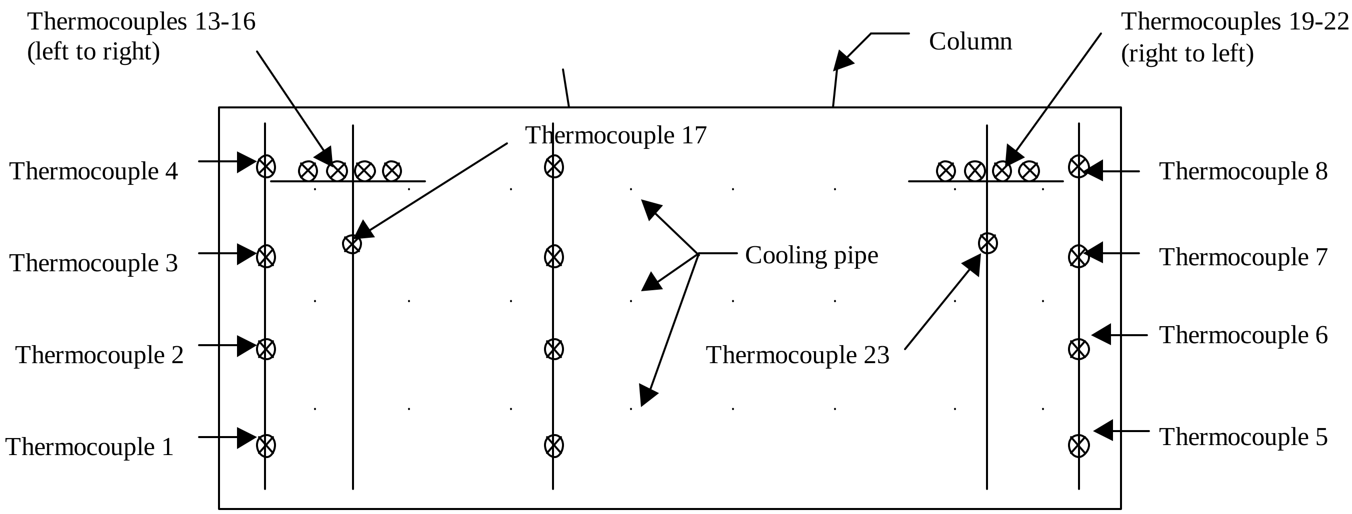
FOOTING SECTION

FIGURE 7 - TYPICAL THERMOCOUPLE LOCATIONS - NO COOLING
NO SCALE

This drawing is accurate for thermocouple locations only.



FOOTING PLAN



FOOTING SECTION

FIGURE 8 - THERMOCOUPLE LOCATIONS (BENT 18)– COOLING INCLUDED

NO SCALE

This drawing is accurate for thermocouple locations only.

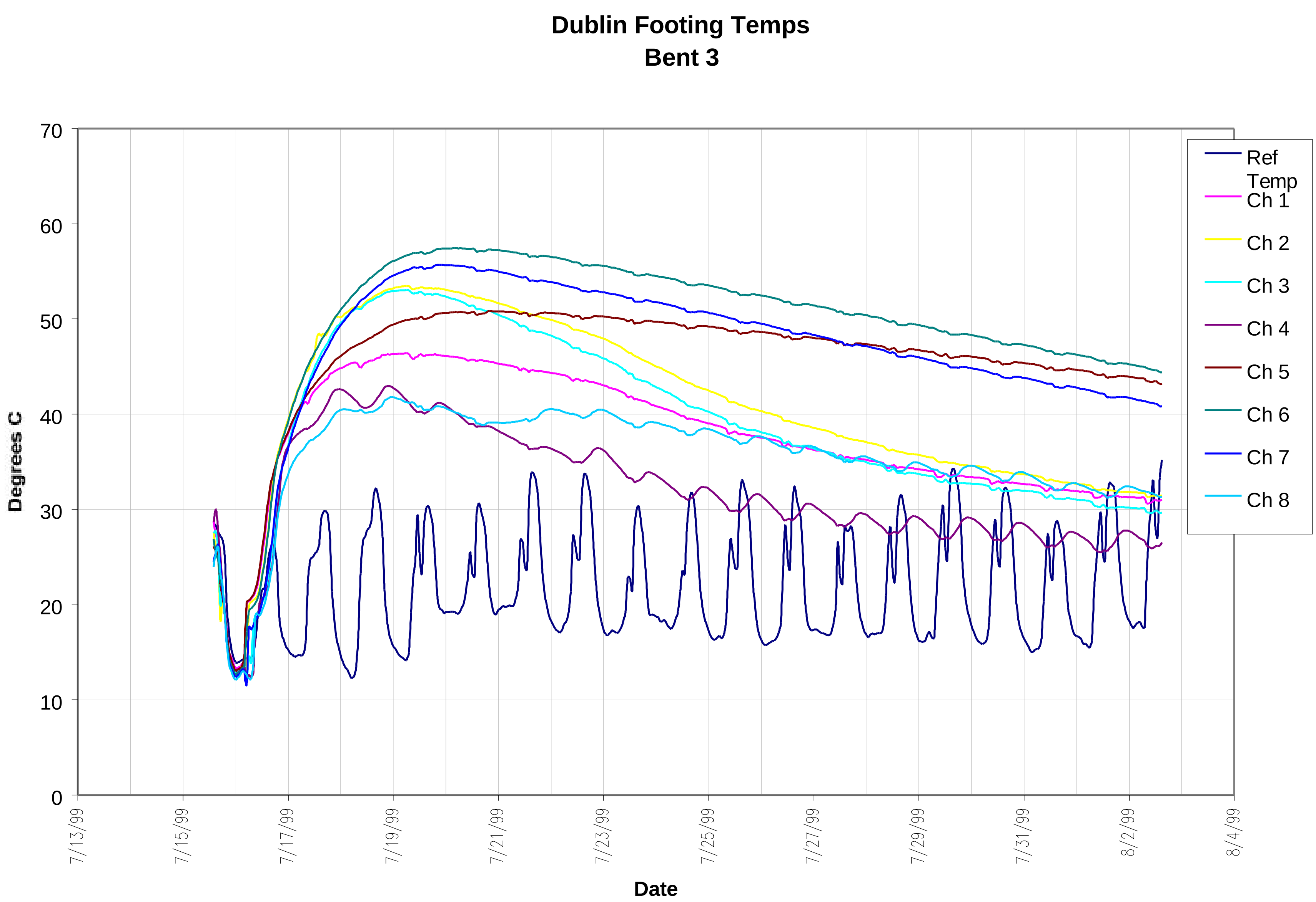
VII. SAMPLE DATA TABLE

Julian Day	hour	Date	Ref Temp	Ch 1	Ch 2	Ch 3	Ch 4	Ch 5	Ch 6	Ch 7	Ch 8
265	1300	9/21/99 1:00 PM	28.27	27.72	29.63	30.08	29.95	27.37	28.5	28.7	28.62
265	1400	9/21/99 2:00 PM	30.02	29.24	31.89	33.43	33.53	29.79	30.69	30.89	30.92
265	1500	9/21/99 3:00 PM	30.7	30.55	32.57	32.12	32.87	29.82	30.52	30.62	30.52
265	1600	9/21/99 4:00 PM	31.57	31.97	32.09	32.29	32.49	30.45	32.99	31.12	31.17
265	1700	9/21/99 5:00 PM	31.96	29.01	30.34	31.64	30.94	29.76	30.24	30.54	29.94
265	1800	9/21/99 6:00 PM	30.14	27.03	27.13	27.2	27.25	27.3	27.33	27.15	26.9
265	1900	9/21/99 7:00 PM	27.33	24.46	24.46	24.41	24.38	24.94	24.86	24.66	24.36
265	2000	9/21/99 8:00 PM	24.94	22.76	22.73	22.68	22.53	23.32	23.19	22.96	22.63
265	2100	9/21/99 9:00 PM	22.86	21.02	20.97	20.95	20.79	21.66	21.46	21.2	20.85
265	2200	9/21/99 10:00 PM	21.27	20.05	20.05	20	19.89	20.51	20.35	20.23	20.05
265	2300	9/21/99 11:00 PM	19.82	18.36	18.26	18.18	18.08	18.8	18.59	18.39	18.13
265	2400	9/22/99 12:00 AM	18.55	17.55	17.47	17.45	17.37	17.93	17.73	17.57	17.42
266	100	9/22/99 1:00 AM	17.74	17.15	17.07	17.02	16.92	17.43	17.23	17.07	16.97
266	200	9/22/99 2:00 AM	17.32	17.29	17.24	17.19	17.14	17.32	17.24	17.16	17.09
266	300	9/22/99 3:00 AM	16.97	17	16.94	16.89	16.82	17.1	17.05	16.92	16.79
266	400	9/22/99 4:00 AM	16.8	17.06	16.98	17.01	16.93	17.14	17.09	17.01	16.91
266	500	9/22/99 5:00 AM	16.65	17.06	17.03	17.03	16.98	17.03	17.03	16.98	16.98
266	600	9/22/99 6:00 AM	16.97	17.15	17.2	17.3	17.2	17.18	17.33	17.33	17.3
266	700	9/22/99 7:00 AM	16.9	17.08	16.95	16.95	16.85	16.92	17.05	16.98	16.95
266	800	9/22/99 8:00 AM	17.01	16.34	16.67	17.16	17.47	19.62	16.54	16.16	16.23
266	900	9/22/99 9:00 AM	17.56	19.82	16.38	16.28	16.97	19.82	16.94	16.33	17.02
266	1000	9/22/99 10:00 AM	18.61	19.94	16.82	16.82	18.36	19.97	16.97	16.58	18.25
266	1100	9/22/99 11:00 AM	18.55	20.14	18.91	18.86	18.09	20.22	18.42	17.78	18.65
266	1200	9/22/99 12:00 PM	20.42	20.27	19.14	19.76	19.14	20.5	18.91	19.48	18.71
266	1300	9/22/99 1:00 PM	22.59	20.58	19.35	19.91	19.89	21.11	19.17	19.61	19.5
266	1400	9/22/99 2:00 PM	24.71	21.15	19.57	20.06	20.64	22.07	19.42	19.78	22.43
266	1500	9/22/99 3:00 PM	27.32	22.06	19.86	20.35	21.22	23.33	19.81	20.2	22.69

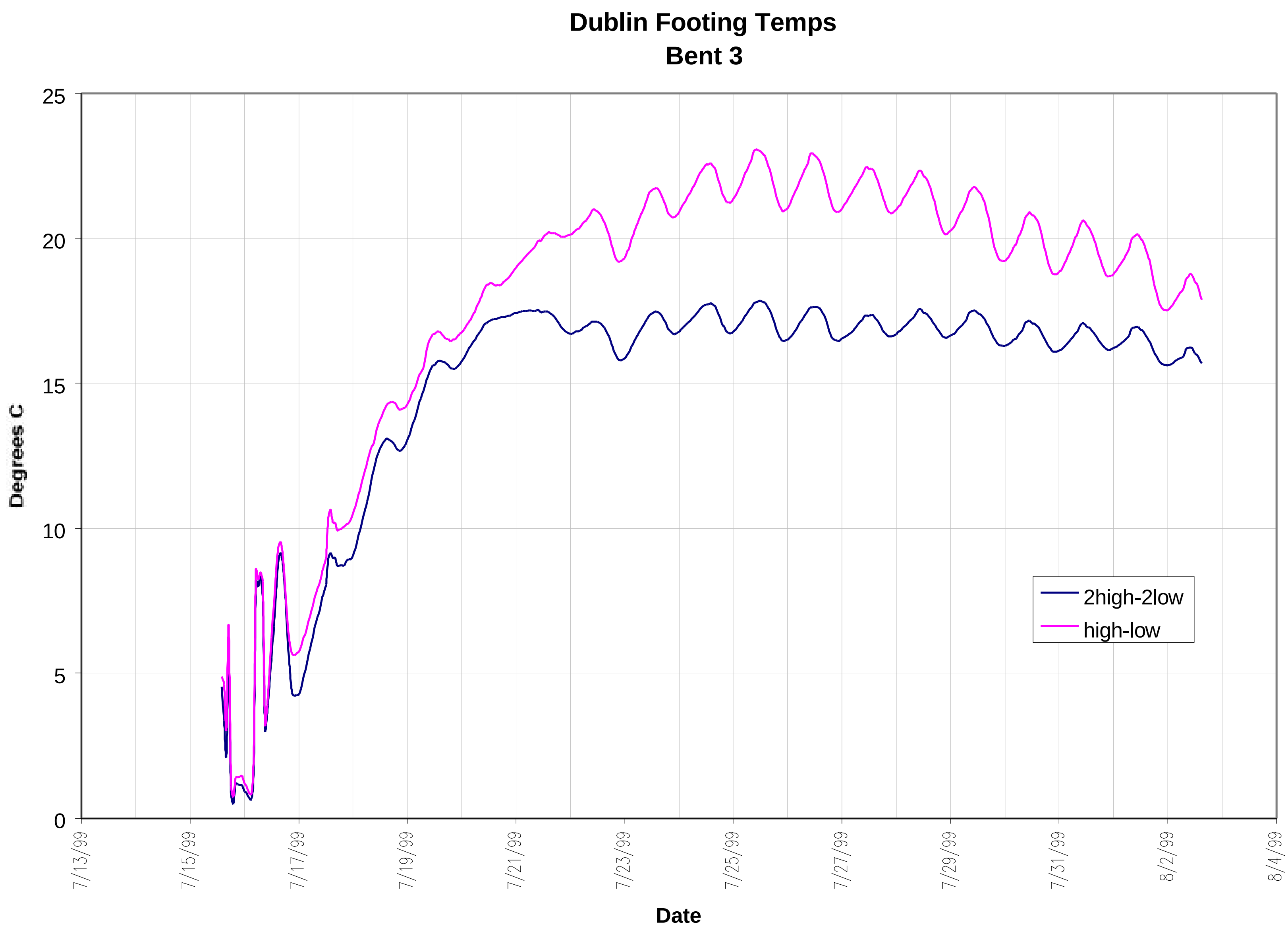
VIII. DATA PLOTS

Table 2. Index of plots.

The plots of temperature difference that follow include a plot which represents the difference between the two extreme values and a second plot that show the difference between the 2nd highest temperature measurement and the second lowest.



Dublin Footing Temps
Bent 3
Degrees C
70
60
50
40
30
20
10
0
7/13/99
7/15/99
7/17/99
7/19/99
7/21/99
7/23/99
7/25/99
7/27/99
7/29/99
7/31/99
8/2/99
8/4/99
Date
Ref Temp
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 6
Ch 7
Ch 8


Dublin Footing Temps
Bent 3
Degrees C
0
5
10
15
20
25
7/13/99
7/15/99
7/17/99
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7/21/99
7/23/99
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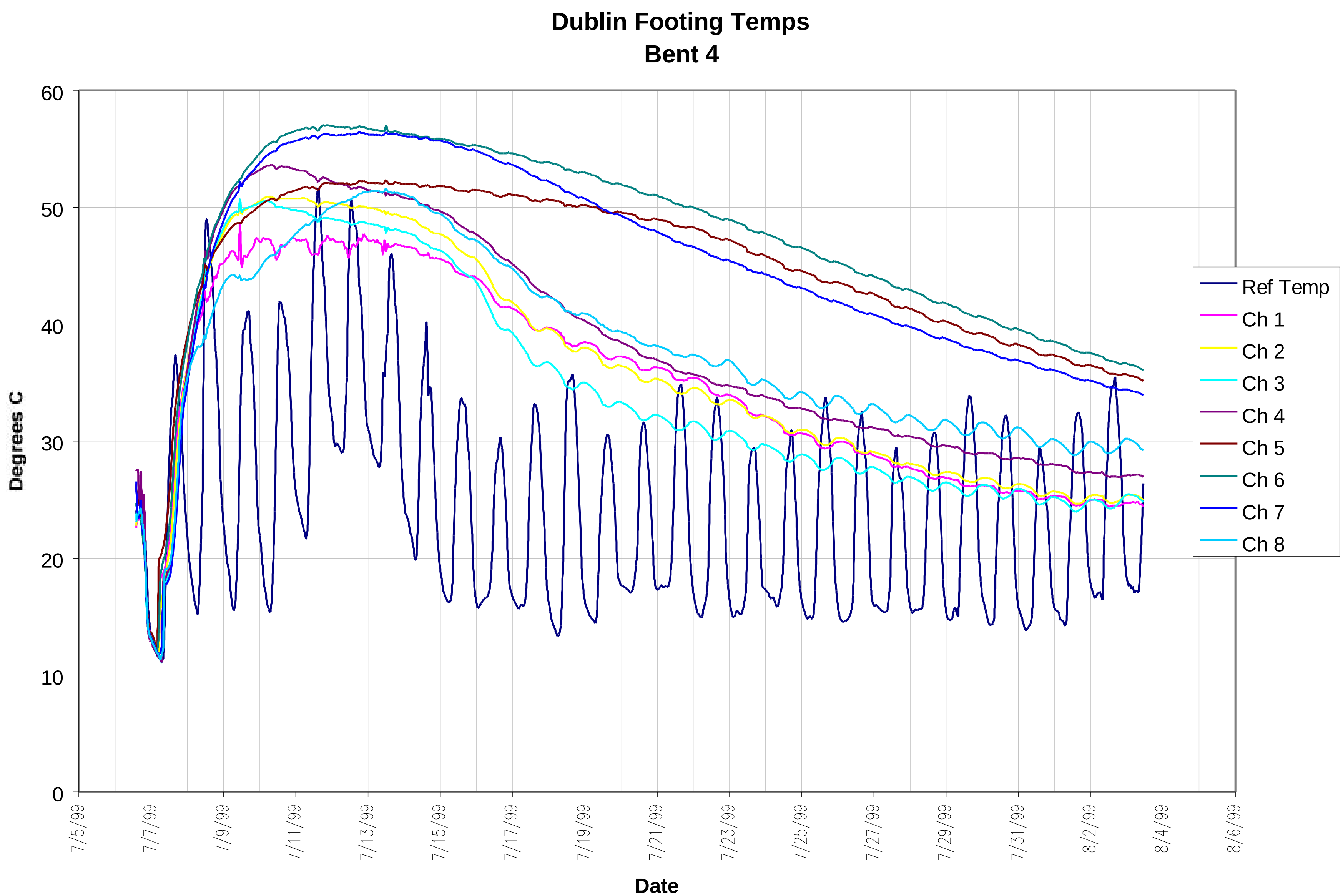
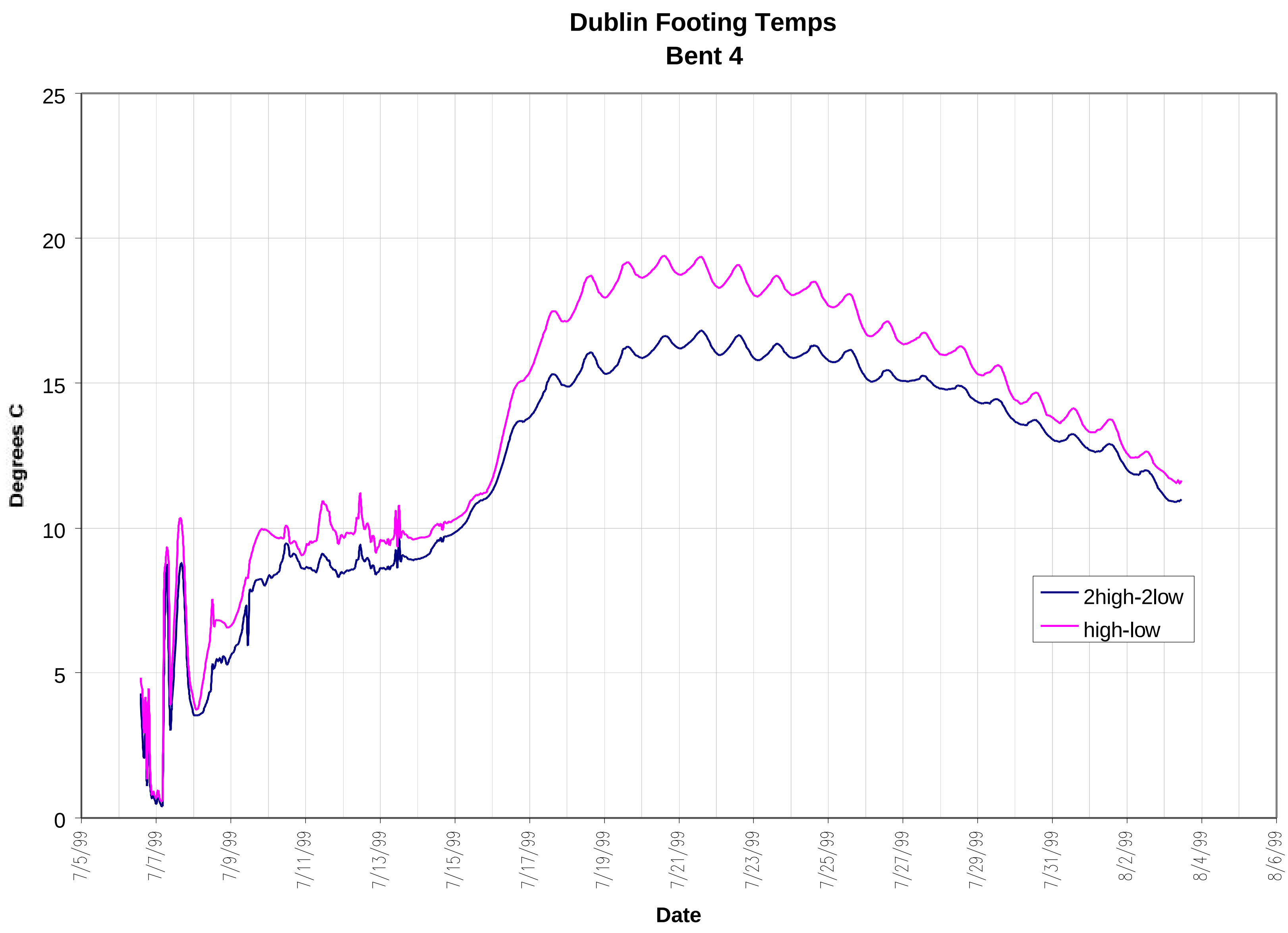
Date
2high-2low
high-low



Dublin Footing Temps
Bent 4
Degrees C
0
10
20
30
40
50
60
7/5/99
7/7/99
7/9/99
7/11/99
7/13/99
7/15/99
7/17/99
7/19/99
7/21/99
7/23/99
7/25/99
7/27/99
7/29/99
7/31/99
8/2/99
8/4/99
8/6/99
Date
Ref Temp
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 6
Ch 7
Ch 8


Dublin Footing Temps
Bent 4
Degrees C
25
20
15
10
5
0
7/5/99
7/7/99
7/9/99
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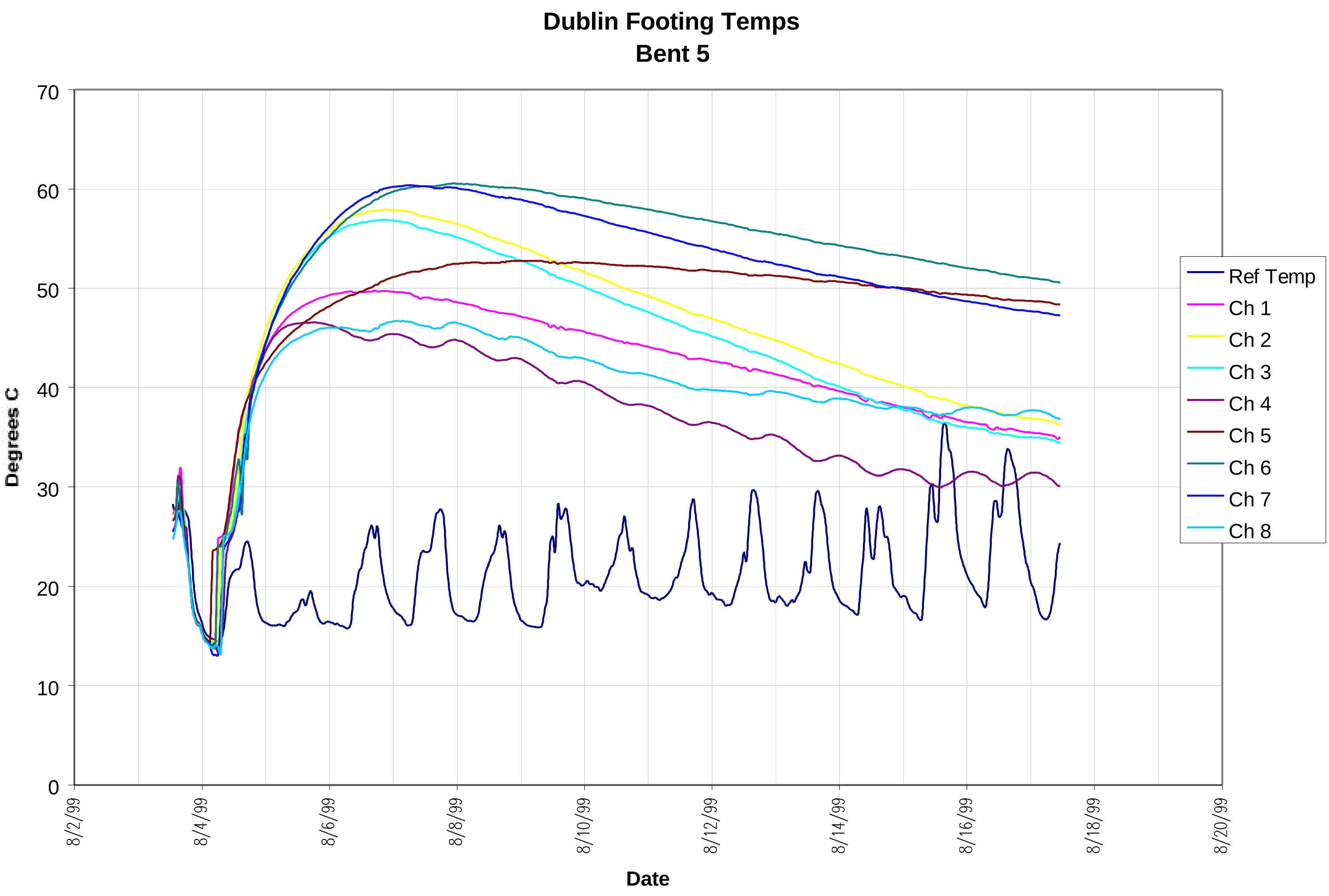
7/13/99
7/15/99
7/17/99
7/19/99
7/21/99
7/23/99
7/25/99
7/27/99
7/29/99
7/31/99
8/2/99
8/4/99
8/6/99
Date
2high-2low
high-low


Dublin Footing Temps
Bent 5
Degrees C
70
60
50
40
30
20
10
0
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8/4/99
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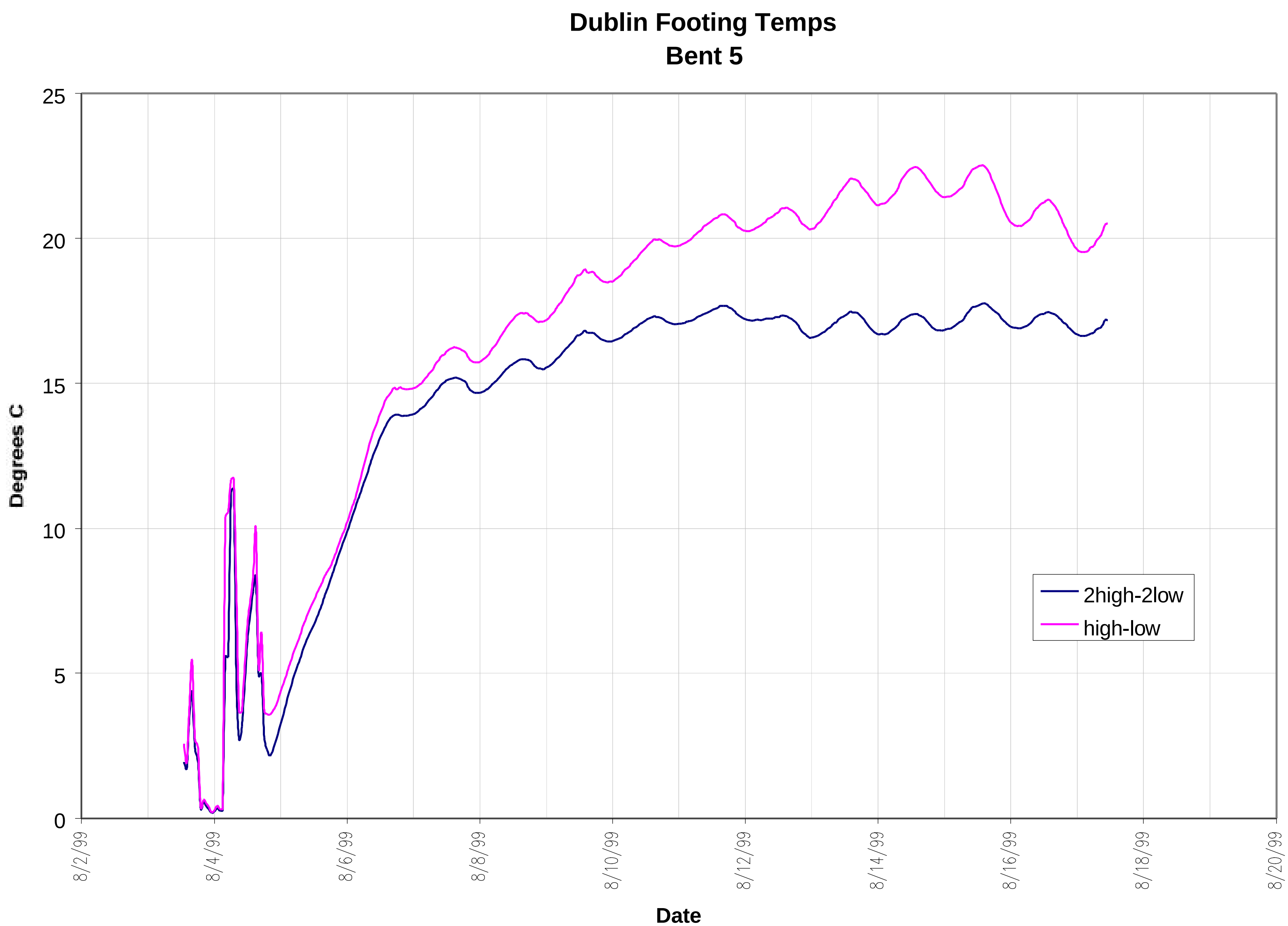
8/8/99
8/10/99
8/12/99
8/14/99
8/16/99
8/18/99
8/20/99
Date
Ref Temp
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 6
Ch 7
Ch 8



Dublin Footing Temps
Bent 5
Degrees C
25
20
15
10
5
0
8/2/99
8/4/99
8/6/99
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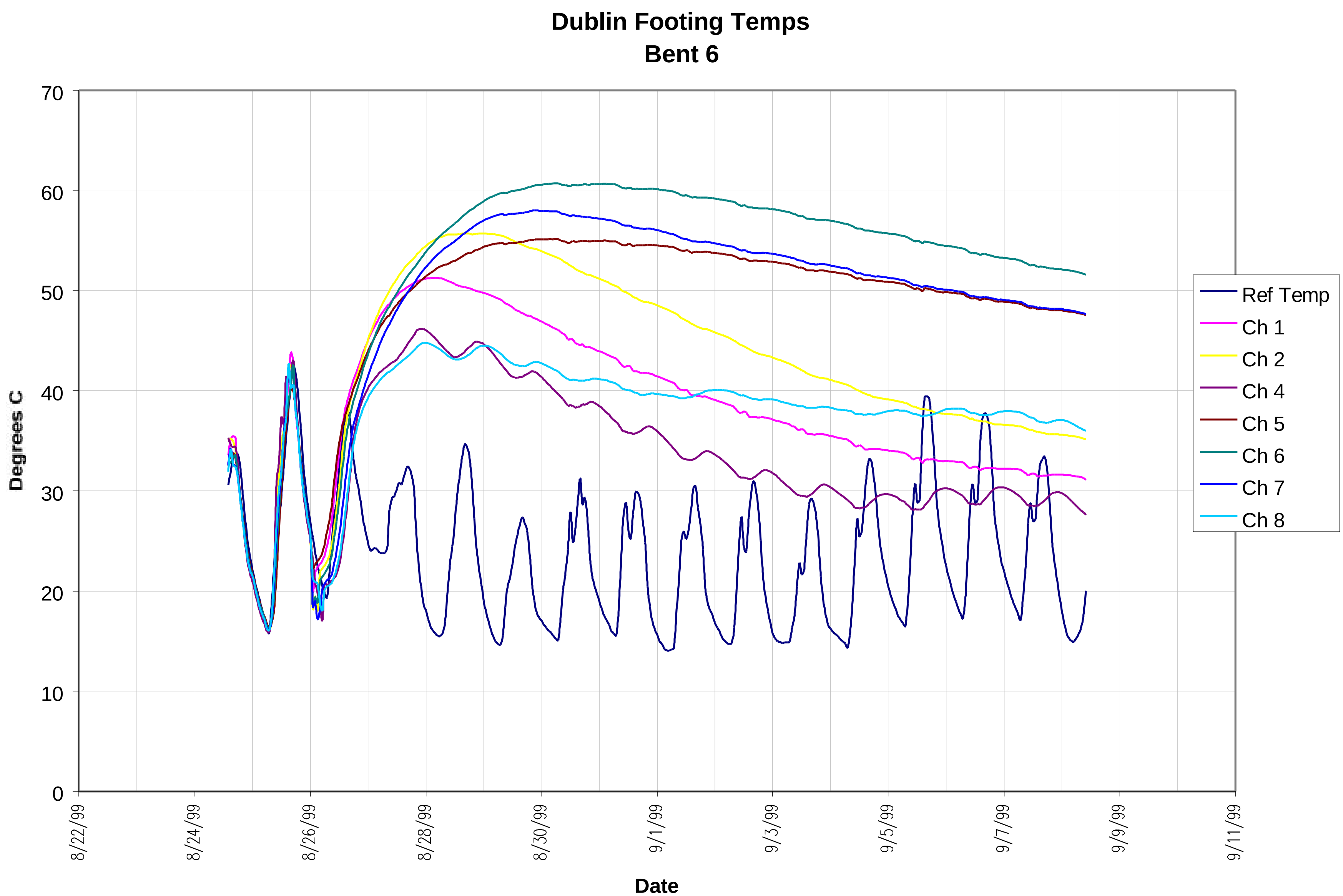
8/20/99
Date
2high-2low
high-low


Dublin Footing Temps
Bent 6
Degrees C
0
10
20
30
40
50
60
70
8/22/99
8/24/99
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8/28/99
8/30/99
9/1/99
9/3/99
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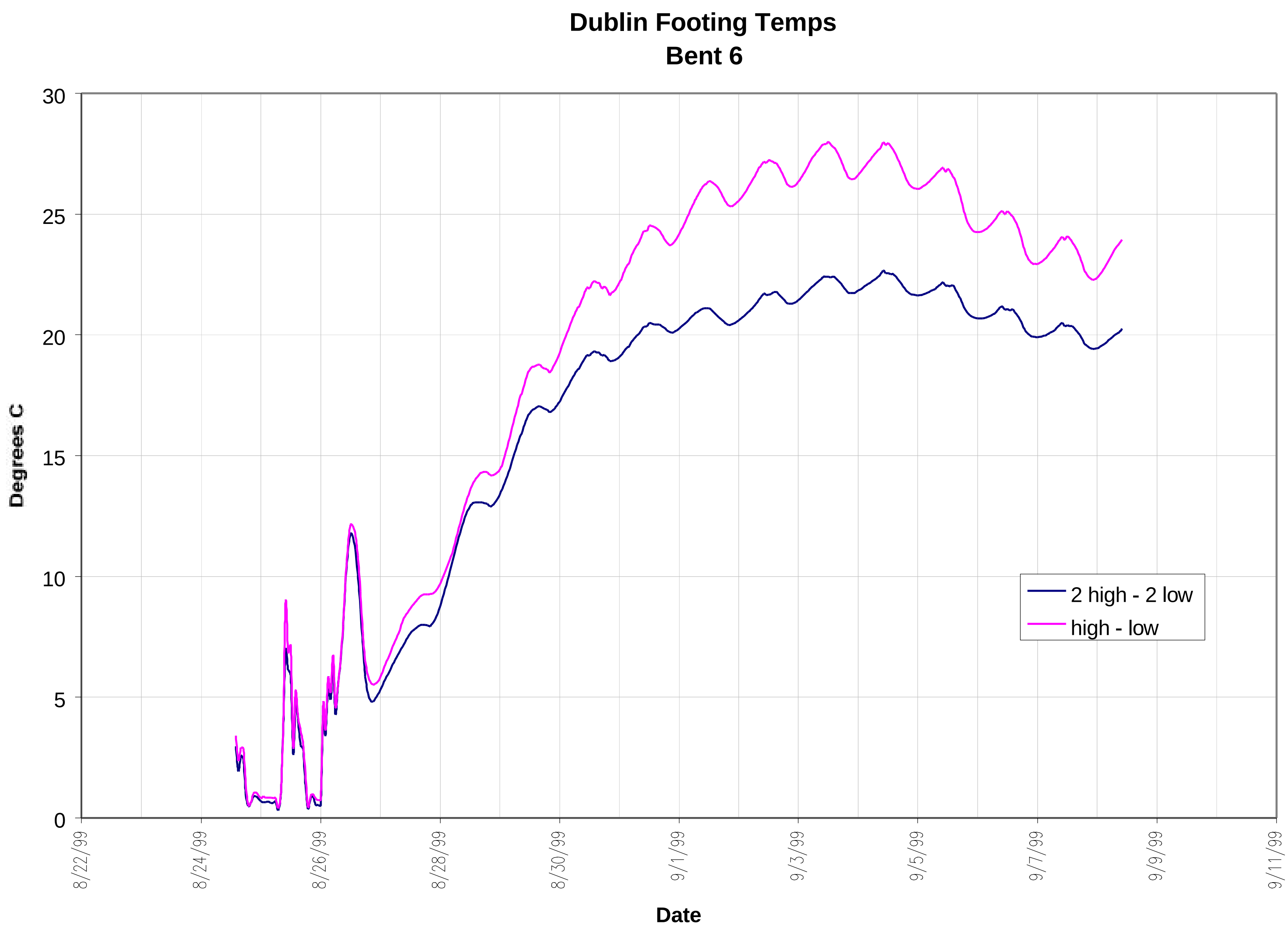
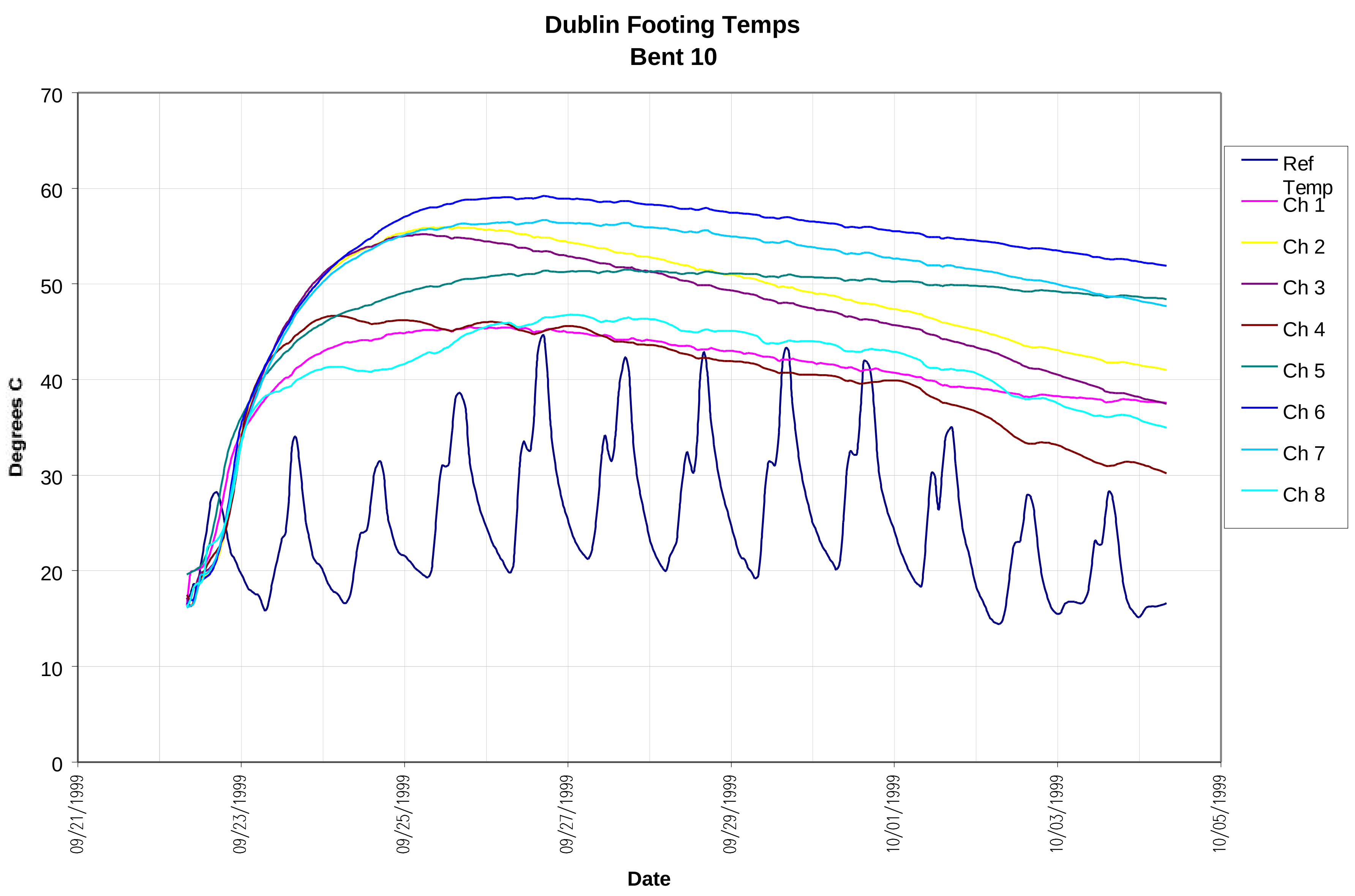
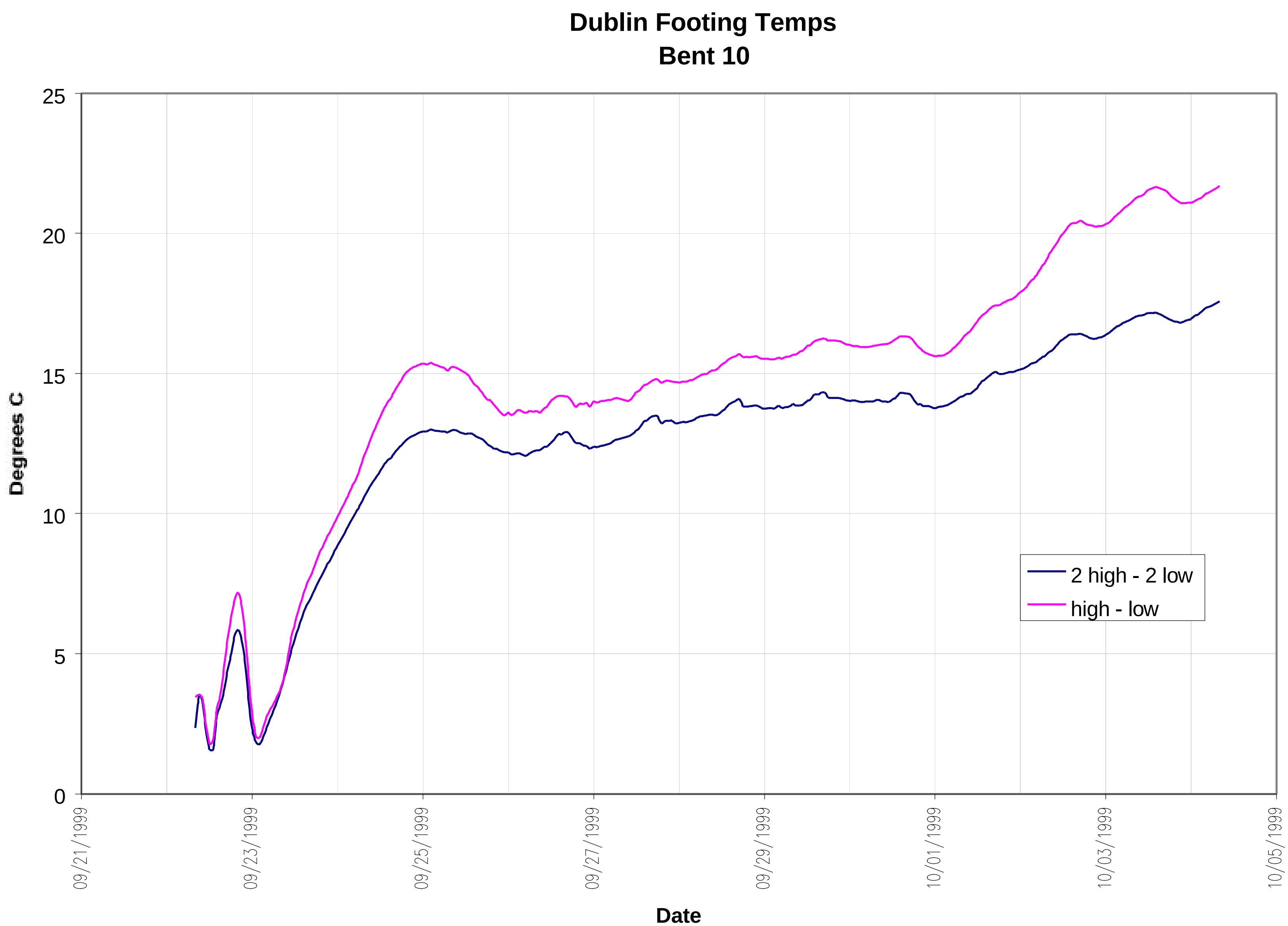
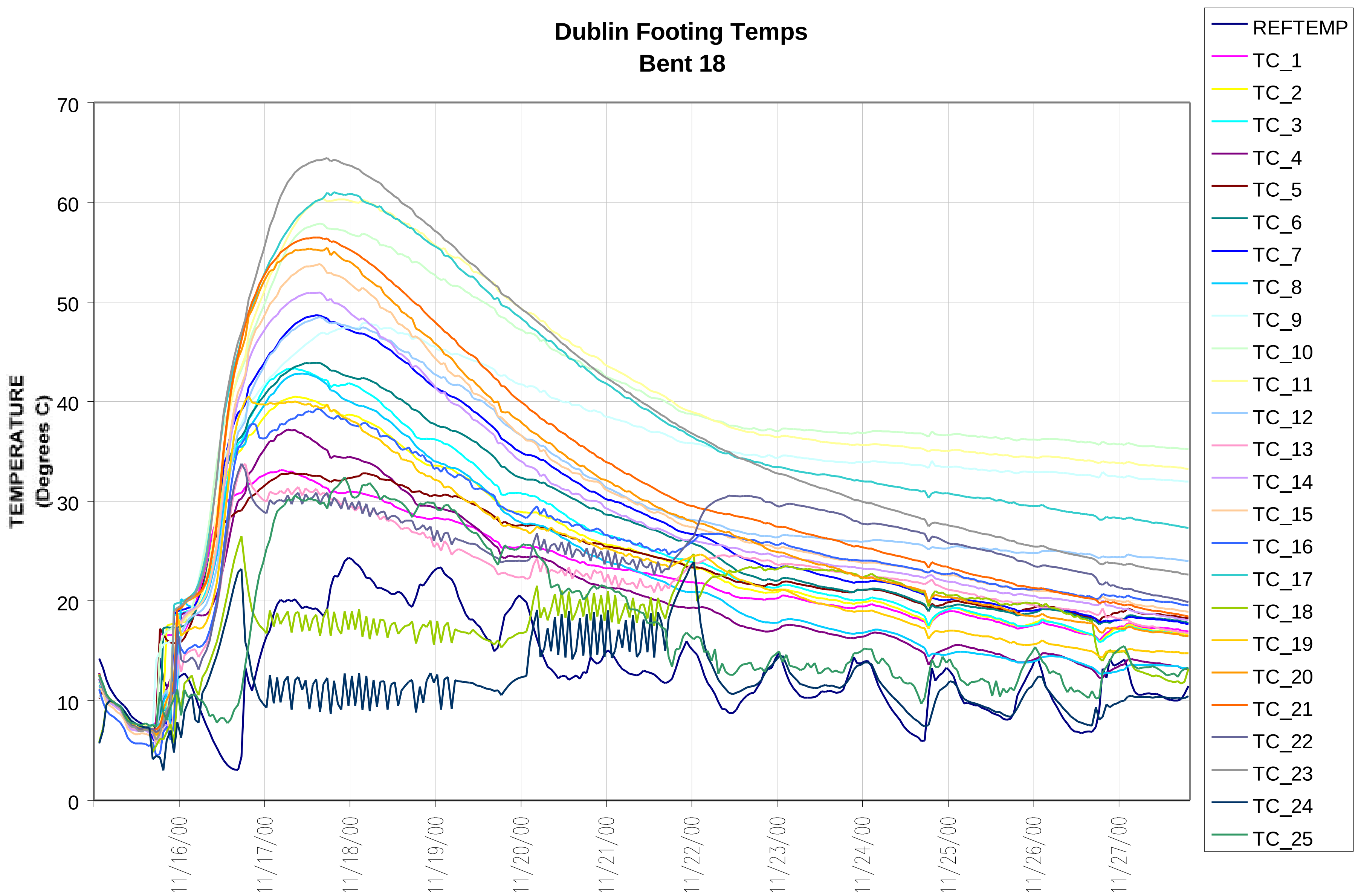
Ch 2
Ch 4
Ch 5
Ch 6
Ch 7
Ch 8


Dublin Footing Temps
Bent 6
Degrees C
30
25
20
15
10
5
0
8/22/99
8/24/99
8/26/99
8/28/99
8/30/99
9/1/99
9/3/99
9/5/99
9/7/99
9/9/99
9/11/99
Date
2 high - 2 low
high - low



Dublin Footing Temps
Bent 10
Degrees C
70
60
50
40
30
20
10
0
09/21/1999
09/23/1999
09/25/1999
09/27/1999
09/29/1999
10/01/1999
10/03/1999
10/05/1999
Date
Ref Temp
Ch 1
Ch 2
Ch 3
Ch 4
Ch 5
Ch 6
Ch 7
Ch 8


Dublin Footing Temps
Bent 10
Degrees C
25
20
15
10
5
0
09/21/1999
09/23/1999
09/25/1999
09/27/1999
09/29/1999
10/01/1999
10/03/1999
10/05/1999
Date
2 high - 2 low
high - low


Dublin Footing Temps
Bent 18
TEMPERATURE
(Degrees C)
0
10
20
30
40
50
60
70
11/16/00
11/17/00
11/18/00
11/19/00
11/20/00
11/21/00
11/22/00
11/23/00
11/24/00
11/25/00
11/26/00
11/27/00
REFTEMP
TC_1
TC_2
TC_3
TC_4
TC_5
TC_6
TC_7
TC_8
TC_9
TC_10
TC_11
TC_12
TC_13
TC_14
TC_15
TC_16
TC_17
TC_18
TC_19
TC_20
TC_21
TC_22
TC_23
TC_24
TC_25

IX. DATA ACQUISITION PROGRAMS

Campbell Datalogger program for 8 temperature channels prepared using the PC208W program.

```
;{21X}
*Table 1 Program
  01: 3600      Execution Interval (seconds)

1:  Internal Temperature (P17)
 1: 1        Loc [ reftemp   ]

2:  Thermocouple Temp (DIFF) (P14)
 1: 8        Reps
 2: 1        5 mV Slow Range
 3: 1        DIFF Channel
 4: 1        Type T (Copper-Constantan)
 5: 1        Ref Temp (Deg. C) Loc [ reftemp   ]
 6: 2        Loc [ temp1_1   ]
 7: 1        Mult
 8: 0        Offset

3:  Batt Voltage (P10)
 1: 10       Loc [ batvol    ]

4:  Do (P86)
 1: 10       Set Output Flag High

5:  Real Time (P77)
 1: 110      Day,Hour/Minute (midnight = 0000)

6:  Sample (P70)
 1: 10       Reps
 2: 1        Loc [ reftemp   ]

*Table 2 Program
  01: 0.0000    Execution Interval (seconds)

*Table 3 Subroutines

End Program

1      [ reftemp   ]  RW--   2       1       ----- ------ ---
2      [ temp1_1   ]  RW--   1       1       Start ------ ---
3      [ temp1_2   ]  RW--   1       1       ----- Member ---
4      [ temp1_3   ]  RW--   1       1       ----- Member ---
5      [ temp1_4   ]  RW--   1       1       ----- Member ---
6      [ temp1_5   ]  RW--   1       1       ----- Member ---
7      [ temp1_6   ]  RW--   1       1       ----- Member ---
8      [ temp1_7   ]  RW--   1       1       ----- Member ---
9      [ temp1_8   ]  RW--   1       1       ----- ------ End
10     [ batvol    ]  -W--   0       1       ----- ------ ---
11     [ _________ ]  ----   0       0       ----- ------ ---
12     [ _________ ]  ----   0       0       ----- ------ ---
13     [ _________ ]  ----   0       0       ----- ------ ---
14     [ _________ ]  ----   0       0       ----- ------ ---
```

Campbell Datalogger program for 32 temperature channels prepared using the PC208W program.

```
;{21X}
;
*Table 1 Program
  01: 3600      Execution Interval (seconds)

1:  Internal Temperature (P17)
 1: 1        Loc [ reftemp   ]

2:  Batt Voltage (P10)
 1: 18       Loc [ battery   ]

3:  Set Port (P20)
 1: 1        Set High
 2: 1        Port Number

4:  Beginning of Loop (P87)
 1: 0        Delay
 2: 16       Loop Count

     5:  Excitation with Delay (P22)
      1: 1        Ex Channel
      2: 1        Delay w/Ex (units = 0.01 sec)
      3: 1        Delay After Ex (units = 0.01 sec)
      4: 5000     mV Excitation

     6:  Thermocouple Temp (DIFF) (P14)
      1: 1        Reps
      2: 1        5 mV Slow Range
      3: 1        DIFF Channel
      4: 1        Type T (Copper-Constantan)
      5: 1        Ref Temp (Deg. C) Loc [ reftemp   ]
      6: 2     -- Loc [ TC_1      ]
      7: 1.0      Mult
      8: 0.0      Offset

     7:  Thermocouple Temp (DIFF) (P14)
      1: 1        Reps
      2: 1        5 mV Slow Range
      3: 2        DIFF Channel
      4: 1        Type T (Copper-Constantan)
      5: 1        Ref Temp (Deg. C) Loc [ reftemp   ]
      6: 19    -- Loc [ TC_17     ]
      7: 1.0      Mult
      8: 0.0      Offset

8:  End (P95)

9:  Do (P86)
 1: 10       Set Output Flag High

10:  Real Time (P77)
 1: 220      Day,Hour/Minute (midnight = 2400)

11:  Sample (P70)
 1: 34       Reps
 2: 1        Loc [ reftemp   ]
```

*Table 2 Program
 02: 0.0000   Execution Interval (seconds)

*Table 3 Subroutines

End Program

```
1     [ reftemp   ]  RW--   3      1      ----- ------ ---
2     [ TC_1      ]  RW--   1      1      ----- ------ ---
3     [ TC_2      ]  R---   1      0      ----- ------ ---
4     [ TC_3      ]  R---   1      0      ----- ------ ---
5     [ TC_4      ]  R---   1      0      ----- ------ ---
6     [ TC_5      ]  R---   1      0      ----- ------ ---
7     [ TC_6      ]  R---   1      0      ----- ------ ---
8     [ TC_7      ]  R---   1      0      ----- ------ ---
9     [ TC_8      ]  R---   1      0      ----- ------ ---
10    [ TC_9      ]  R---   1      0      ----- ------ ---
11    [ TC_10     ]  R---   1      0      ----- ------ ---
12    [ TC_11     ]  R---   1      0      ----- ------ ---
13    [ TC_12     ]  R---   1      0      ----- ------ ---
14    [ TC_13     ]  R---   1      0      ----- ------ ---
15    [ TC_14     ]  R---   1      0      ----- ------ ---
16    [ TC_15     ]  R---   1      0      ----- ------ ---
17    [ TC_16     ]  R---   1      0      ----- ------ ---
18    [ battery   ]  RW--   1      1      ----- ------ ---
19    [ TC_17     ]  RW--   1      1      ----- ------ ---
20    [ TC_18     ]  R---   1      0      ----- ------ ---
21    [ TC_19     ]  R---   1      0      ----- ------ ---
22    [ TC_20     ]  R---   1      0      ----- ------ ---
23    [ TC_21     ]  R---   1      0      ----- ------ ---
24    [ TC_22     ]  R---   1      0      ----- ------ ---
25    [ TC_23     ]  R---   1      0      ----- ------ ---
26    [ TC_24     ]  R---   1      0      ----- ------ ---
27    [ TC_25     ]  R---   1      0      ----- ------ ---
28    [ TC_26     ]  R---   1      0      ----- ------ ---
29    [ TC_27     ]  R---   1      0      ----- ------ ---
30    [ TC_28     ]  R---   1      0      ----- ------ ---
31    [ TC_29     ]  R---   1      0      ----- ------ ---
32    [ TC_30     ]  R---   1      0      ----- ------ ---
33    [ TC_31     ]  R---   1      0      ----- ------ ---
34    [ TC_32     ]  R---   1      0      ----- ------ ---
35    [ _________ ]  ----   0      0      ----- ------ ---
36    [ _________ ]  ----   0      0      ----- ------ ---
37    [ _________ ]  ----   0      0      ----- ------ ---
38    [ _________ ]  ----   0      0      ----- ------ ---
39    [ _________ ]  ----   0      0      ----- ------ ---
40    [ _________ ]  ----   0      0      ----- ------ ---
41    [ _________ ]  ----   0      0      ----- ------ ---
42    [ _________ ]  ----   0      0      ----- ------ ---
43    [ _________ ]  ----   0      0      ----- ------ ---
```